Coupled Ocean-Atmosphere Processes and European Climate

COAPEC

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Newsletter No 2: August 2002

The second of an irregular series of Newsletters with brief reports on meetings and projects associated with the NERC's COAPEC thematic Programme

Programme News

The COAPEC programme is now half way through its five year life-span as a Natural Environment Research Council Thematic programme. A total of 20 projects have been funded, the details of which can be found on the COAPEC web site (http://coapec.nerc.ac.uk) under the link to "Programme Awards". In the final round of funding, there was a call for projects addressing "new observations in support of COAPEC science" and one project was funded in this call - "Argo floats in the South Atlantic" (Brian King, SOC). There was also a call for projects addressing one of the key COAPEC themes of "bridging the gap between scientific output and societal needs". Two projects were funded in this call - "climate information for the health sector" (Glenn McGregor, Birmingham) and "quantifying the economic value of coupled ocean-atmosphere model ensemble forecasts for decision making within the UK energy industry" (David Stephenson, Reading).

Many of the earlier projects are now under way and starting to produce interesting results, many of which were reported at the annual meeting (see below). The core team have continued to be active - both in support of existing projects and in their personal research topics. New models are being developed and made available for use by the COAPEC community (see, *e.g.* the report on FORTE on page 4). Several of the PhD students have also started and we expect to welcome several more starting in October.

On the Cross-Equator Coherence of the Interannual Energy Transport Variability in the Tropical Atlantic Ocean of HadCM3

Len Shaffrey (L.C.Shaffrey@reading.ac.uk) and Rowan Sutton, CGAM, Department of Meteorology, University of Reading.

In Dong and Sutton (2001) it was found that the interannual variability of the poleward energy transport in the tropical Atlantic Ocean of the Met Office's coupled climate model (HadCM3) is characterised by significant coherence across the equator. However, the exact processes that led to the coherence remained unclear. An explanation for the spatial coherence is suggested by figure 1 which shows that the variability of the tropical Atlantic Ocean energy transport is dominated by changes in the strength of the western boundary current. The changes in the western boundary current are spatially coherent right across the tropics, extending from 10˚S to 15˚N.

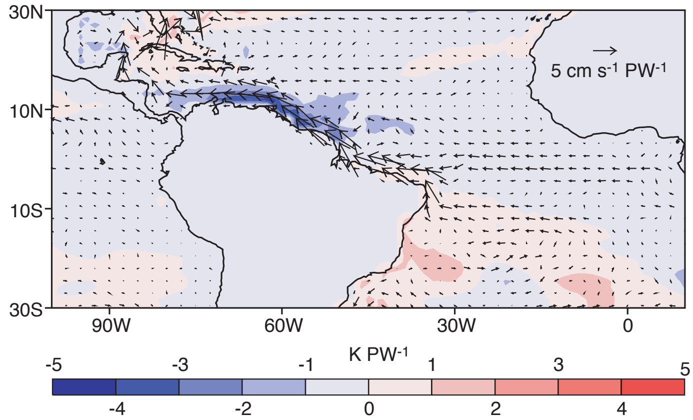

Figure 1. Mean currents (vectors) and temperatures (contours) in the upper 375 m of the ocean regressed against the annual mean Atlantic Ocean energy transport averaged between 20˚S and 20˚N.

The changes in the western boundary current result from an adjustment of the tropical Atlantic Ocean to a strengthening of the easterly trade winds along the north coast of South America (figure 2). The strengthening of the easterly trades induces coastal upwelling along the Venezuelan coastline. The strong cold anomaly associated with the coastal upwelling propagates southward along the South American

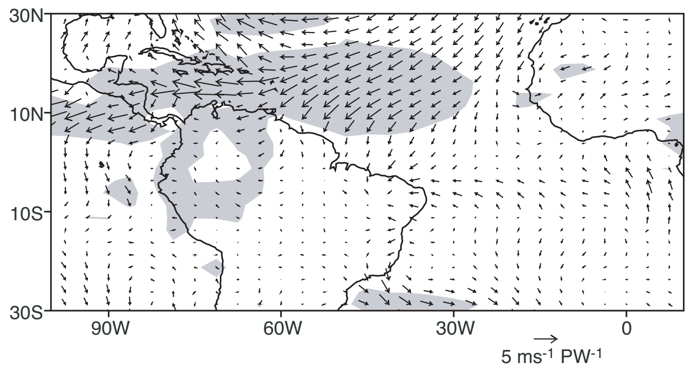

Figure 2. Surface winds regressed against the annual mean Atlantic Ocean energy transport averaged between 20˚S and 20˚N. Shading denotes regions where one of the components of the regression is 95% significant.

coastline as an upwelling Kelvin wave until it reaches the equator. At the equator an equatorial Kelvin wave is excited, which travels across the basin and excites two coastally trapped Kelvin waves, which travel north and south along the eastern boundary. The coastally trapped Kelvin waves in turn excite westward travelling Rossby waves which radiate into the interior of the Atlantic.

The extent of the adjustment of the South Atlantic to the baroclinic Rossby waves can be seen in figure 1 as the zero line that curves from 10˚S on the western boundary to 30˚S on the eastern boundary. The zero line has this characteristic curve as the baroclinic Rossby wave propagation speeds are strongly dependent on latitude. The Rossby waves propagate relatively quickly near the equator (months to cross the basin) but much more slowly near 30˚S (years to cross the basin). The spatial coherence of the interannual variability in the tropical western boundary current and the tropical Atlantic Ocean energy transport are a result of the fast adjustment of the tropical Atlantic Ocean.

References:

Dong, B.W. and R.T. Sutton (2001). The dominant mechanisms of variability in Atlantic ocean heat transport in a coupled ocean-atmosphere GCM. *Geophy. Res. Let.*, **28**, 2445-2448.

Impact of Individual ENSO events on the North Atlantic European Region

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Observational and modelling evidence suggest that the El Niño Southern Oscillation (ENSO) has a weak, but significant, impact over the North Atlantic European (NAE) region. The physical nature and regional details of the remote response, however, remain controversial. The impact of ENSO over Europe is traditionally viewed as resulting from the extension of the PNA wave-train emanating from the tropical Pacific (figure 3). Fraedrich (1994) showed that the pressure response over Europe during El Niño (figure 4) takes the form of a meridional dipole, with positive (negative) anomaly over Scandinavia (over France and the Black Sea), associated with a southward shift of the storm track and wetter (dryer) conditions over south-central Europe (north-eastern Europe).

The ‘‘average’’ canonical picture of ENSO-NAE teleconnections sketched in figure 3 relies on com-

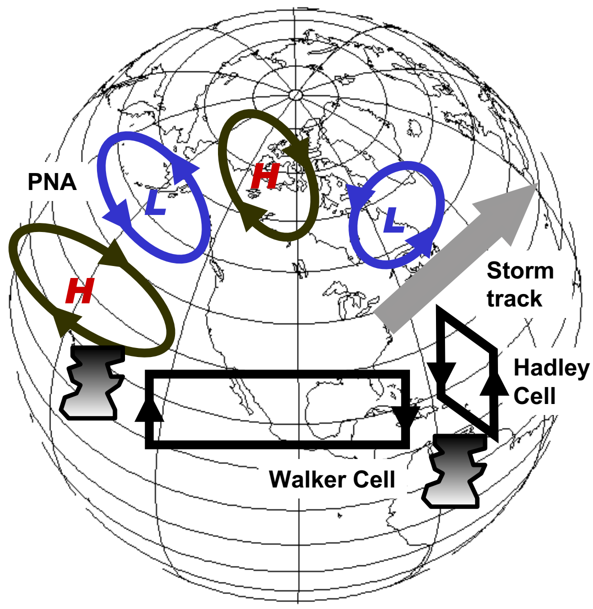

Figure 3. Canonical view of El Niño teleconnections. Schematic of the EN-NAE atmospheric pathways.

posite analysis, which implicitly assumes the *linearity* and *stationarity* of ENSO impacts. This is a major limitation, as in practise, every ENSO is unique and composite studies average out these unique features that may in fact include potentially predictable climate anomalies. In order to address this issue, we have investigated (a) the observed and simulated atmospheric response to *individual* EN and LN events and (b) the specific role of Atlantic SST forcing in modulating the remote ENSO-NAE impact. To achieve this objective, we conducted two ensemble experiments of 10 integrations with the UK Met Office atmospheric model HadAM3 (Pope *et al.*, 2000) with different boundary conditions. The control experiment “GLOB” was forced over the period 1986-2001 by global observed Sea Surface Temperatures (SST). The sensitivity experiment “IPAC” is identical to GLOB in the Indian and Pacific basins but differs in the Atlantic basin (between 30˚S and 75˚N) where climatological SST values are imposed. Our experimental methodology is similar to Dong *et al*. (2000) but extends their results by including six ENSO events.

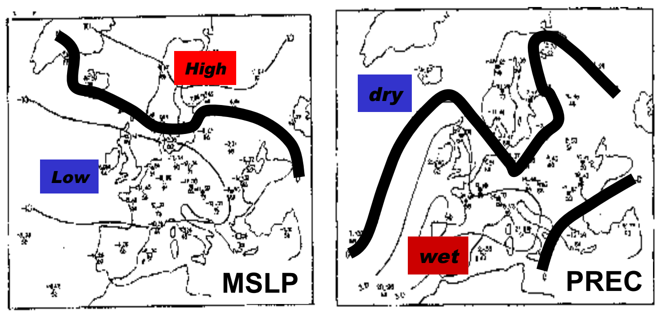

Figure 4. Composite analysis of Fraedrich (1994) for the Mean Sea Level Pressure (MSLP) and Precipitation (PREC) fields over Europe.

Our results, described in Mathieu *et al.* (2002), support the existence of significant, and hence potentially predictable, ENSO related impacts on the climate of the NAE region, but also demonstrate that these impacts can differ considerably from event to event. The differences originate in part from differences in the SST forcing in the Pacific and Indian oceans. In addition, we have shown that the tropical Atlantic SST forcing can lead to significant modifications of the Pacific response by shifting the meridional Hadley cell and by forcing Rossby wave activity (figure 3). This potentially important role of the Atlantic as a key link in the ENSO-NAE teleconnection chain is not surprising but has been hardly stressed in the literature. The non-stationarity of ENSO has major implications for seasonal forecasting as it invites us to revisit the classical focus on Niño3 index as the sole important predictor of remote ENSO impacts. In the development of systems for seasonal prediction of NAE climate, attention must not be limited to a narrow focus on the tropical Pacific.

References:

Dong, B.-W., R.T. Sutton, S.P. Jewson, A. O'Neill and J.M. Slingo (2000). Predictable winter climate in the North Atlantic sector during the 1997-1999 ENSO cycle. *Geophys. Res. Let.*, **27**, 985-988.

Fraedrich, K. (1994). An ENSO impact on Europe? A review. *Tellus*, **46A**, 541-552.

Mathieu, P-P., R.T. Sutton, B.-W. Dong and M. Collins (2002). Predictability of winter climate over the North Atlantic European region during ENSO events. *J. Climate*, **in prep.**.

Pope, V. D., M. L. Gallani, P. R. Rowntree and R. A. Stratton (2000). The impact of new physical parametrizations in the Hadley Centre climate model -- HadAM3. *Climate Dynamics*, **16**, 123-146.

CHIME – a New UK Coupled Climate Model

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Bablu Sinha and Adrian New,
Southampton Oceanography Centre

The majority of coupled climate models developed to date use an ocean component with a cartesian vertical coordinate; that is, the model fields at each water column are defined at a set of constant depth levels. This allows the ocean to have arbitrarily high resolution near the surface, but generally leads to excessive diapycnal mixing, especially in sill overflows of dense bottom water. This may have adverse consequences in long-term climate simulations, in particular on the stability of the meridional overturning circulation. Isopycnic models, which use potential density as their vertical coordinate, preserve the

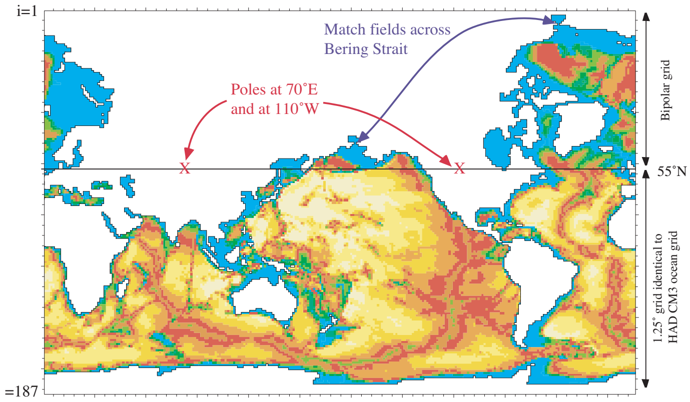

Figure 5. The CHIME Ocean Grid and Bathymetry

structure of water masses faithfully over long times but have poor vertical resolution in weakly stratified regions. The recently introduced hybrid-coordinate models, in which interior isopycnal layers transition to constant-depth levels in near-surface waters, should in principle combine the advantages of both model types without the weaknesses of either.

The Coupled Hadley-Isopycnic Model Experiment (CHIME) is a new coupled model, developed at Southampton Oceanography Centre. It consists of the atmospheric model used in the Hadley Centre's HadCM3 climate model, coupled to a hybrid coordinate ocean model (HYCOM) via the OASIS coupler. The ocean model grid is identical, over most of the globe, to that used in HadCM3, allowing the effect of the different vertical representation of the ocean to be easily assessed. A further innovative feature of CHIME's ocean component is its use of a bipolar grid over the Arctic (see figure 5). This avoids the problem of convergence of meridians toward the North Pole by replacing the latitude-longitude grid north of a given latitude circle (here 55°N) with a bipolar grid. This matches the spherical grid perfectly at this latitude, but its two poles may be placed harmlessly in large land masses.

The coupled model will be spun up on the Origin 3000 supercomputer at Manchester Computing Centre for two hundred years and detailed comparisons will be made with HadCM3. A major part of this analysis will be a COAPEC-funded study of the interannual and decadal variability of the coupled system, in which we will look for correlations between anomalies in sea surface temperature in the north Atlantic with the climate of western Europe.

Runs of the ocean component of CHIME have already been carried out to optimise the model parameters. The ocean model is also being used to evaluate the new balanced flux climatology developed at SOC as part of another COAPEC project (Josey, see http://www.soc.soton.ac.uk/coapec/Josey.php). The coupled model has now been set up, and preliminary runs of a few days have so far been completed.

Climate Predictability on Interannual to Decadal Time Scales: The Initial Value Problem

Mat Collins (mat@met.reading.ac.uk), CGAM, Department of Meteorology, University of Reading

Any initial value forecast of climate will be subject to errors originating from poorly known initial conditions, model imperfections, and by "chaos" in the sense that, even if the initial conditions were perfectly known, infinitesimal errors can amplify and spoil the forecast at some lead time. The latter source of error has been examined using a "perfect ensemble" approach, whereby small perturbations are made to a coupled Atmosphere-Ocean General Circulation Model and the spread of near-by model trajectories, on time and space scales appropriate to seasonal - decadal climate variability, is measured to assess the lead time at which the error saturates. The study therefore represents an estimate of the upper limit of the predictability of climate (appropriate to the initial value problem) given a perfect model and near perfect knowledge of the initial conditions.

It is found that, on average, surface air temperature anomalies are potentially predictability on seasonal to interannual time scales in the tropical regions and are potentially predictable on decadal time scales over the ocean in the North Atlantic. For mid-latitude surface air temperature anomalies over land, model trajectories rapidly diverge and there is little sign of any potential predictability on time scales greater than

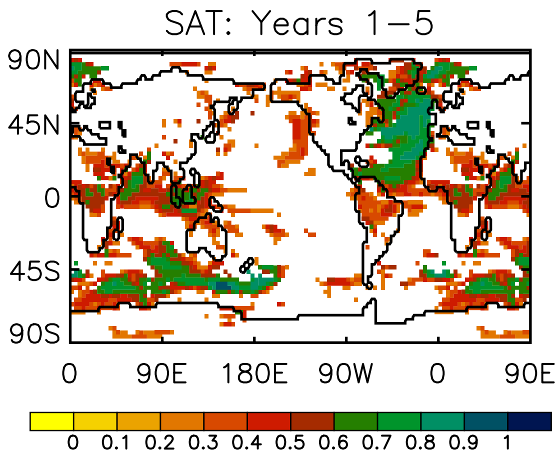

Figure 6. An estimate of the upper limit of climate predictability from HadCM3 "perfect ensemble" experiments. The figure shows anomaly correlation coefficients computed over all twelve 5-member ensemble experiments at each model grid point for 5 year average surface air temperature. Values are only shaded when they are statistically different from zero and the correlation is greater than that for a persistence forecast.

a season or so. For mean sea level pressure anomalies, there is potential predictability on seasonal time scales in the tropics, and for some global scale annual - decadal anomalies, although not those associated with the North Atlantic Oscillation. For precipitation, the only potential for predictability is for seasonal time anomalies associated with the El Niño Southern Oscillation. For the majority of the highly populated regions of the world, climate predictability on interannual to decadal time scales based in the initial value approach is likely to be severely limited by chaotic error growth. It is found however that there can be cases in which the potential predictability can be higher than average indicating that there is perhaps some utility in making initial value forecasts of climate in those regions which show low predictability on average.

References:

Collins, M. (2002). Climate predictability on interannual to decadal time scales: the initial value problem. *Climate Dynamics*, **in press**.

FORTE - a fast, coarse resolution coupled model with realistic physics

Robin Smith (rssmi@soc.soton.ac.uk) and Bablu Sinha, Southampton Oceanography Centre

A coarse resolution coupled model has been developed by coupling the GFDL-derived MOMA ocean model (Webb, 1996) to the spectral IGCM3 atmosphere (Hoskins, 1975; de Forster, 2000) using OASIS (Terray, 1999). The component models are successful stand alone models in their own right and the coupled model retains the full, realistic physics of the individual components. The model can be run on a variety of platforms, including desktop PCs (using Linux and a commercial compiler) and at a variety of resolutions (T21 or T41 in the atmosphere, 4˚ - 1˚ in the ocean).

The coarse resolution makes the model far less computationally expensive than a model like HadCM3 - T21, 4˚ x 4˚ resolution on a dual Athlon 2100XP integrates 12 years per day with synchronous timesteps of 1350 s in all components. This can be increased by means of asynchronous coupling - the use of periodic coupling (Sausen, 1996) has been tested to allow 100 years to be integrated in ~2 days. This makes the model ideal for use in parameter studies, or in guiding the choice of experiments to be run on more accurate models - this feature is currently being exploited to run a number of idealised / paleoclimate simulations.

A 100-year integration of the present climate, ini-

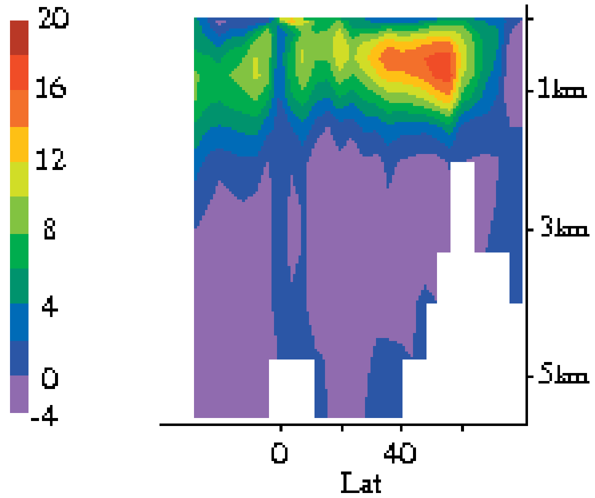

Figure 7. Atlantic Meridional Overturning (Sv) from a 100-year run of the FORTE model.

tialised from Levitus ocean data and an equilibrated atmosphere state (Forster, 2000), has been run at the most coarse resolution (T21, 4˚ x 4˚), which, although still being evaluated, clearly reproduces many of the features of the present climate (figure 7).

The model is currently being run by groups at SOC and Liverpool University and is intended for use as a portable, inexpensive climate test-bed for the community. A technical report is available (Sinha, 2002). Please contact the authors for more information, or visit http://www.soes.soton.ac.uk/research/groups/ocean_climate/forte/ .

References:

de Forster, P.M., M. Blackburn, R. Glover and K.P. Shine (2000). An examination of climate sensitivity for idealised climate change experiments in an intermediate general circulation model. *Climate Dynamics*, **16**, 833-849.

Hoskins, B.J. and A.J. Simmons (1975). A multi-layer spectral model and the semi-implicit method. *Quat. J. R. Met. Soc.*, **101**, 637-655.

Sausen, R. and R. Voss (1996). Techniques for asynchronous and periodically synchronous coupling of atmosphere and ocean models. Part 1: General strategy and application to the cyclo-stationary case. *Climate Dynamics*, **12**, 313-323.

Sinha, B.S, and R.S. Smith (2002). Development of a fast coupled general circulation model (FORTE) for climate studies, implemented using the OASIS coupler. *SOC Internal Document* **No. 81**, 67 pp..

Terray, L.T., S. Valcke and A. Piacentini (1999). OASIS 2.3 User's Guide. *CERFACS internal document* **TR/CGMC/, 99-37**, CERFACS, Toulouse, 82 pp..

Webb, D.J. (1996). An ocean model code for array processor computers. *Computers and Geosci.*, **22**, 569-578

RAPID update

Meric Srokosz, Science Coordinator, SOC (M.Srokosz@soc.soton.ac.uk)

The Rapid Climate Change programme (RAPID) has been funded by NERC to investigate and understand the causes of rapid climate change. RAPID has a main, but not exclusive, focus on the role of the Atlantic Ocean's thermohaline circulation (THC) in such change. Two Announcments of Opportunity (AOs) were issued in January 2002. One called for proposals to investigate various aspects of the science of rapid climate change, the other for proposals to establish a pre-operational prototype system to continuously observe the strength and structure of the Atlantic meridional overturning circulation (MOC – of which the THC is the dominant component). Following an initial outline bid stage, the full proposal deadline was in July and 44 proposals were submitted (39 "science", 5 MOC monitoring). After they have been refereed, funding decisions will be made by the RAPID steering committee in November, with the first projects starting in early 2003. Further AOs for funding will be issued thereafter. Additionally, the NERC issued a call for proposals in July under its Small Business Research Initiative (SBRI) that covered areas of interest to the RAPID programme. Funding decisions on SBRI proposals will be made in November as well.

RAPID is actively developing international collaborations that complement and enhance the work that will be carried out in the UK. As a result of this, an Expression of Interest for a European Union Framework 6 Programme Integrated Project (called WATCHER = Will the Atlantic Thermohaline Circulation Halt; is Europe at Risk?) was submitted to the EU in June 2002. A key collaboration, arising from discussions between the Prime Ministers of the UK and Norway, is with the Norwegian Ocean Climate project (NOClim; http://www.noclim.org), and RAPID provided some travel funds for some UK researchers to attend the NOClim meeting in May. More details of RAPID, including the science and implementation plans and proposed project titles, can be found on the web page http://rapid.nerc.ac.uk/.

For further information about RAPID (or WATCHER) contact the RAPID Science Coordinator (see contact details above).

Meetings

A highly successful meeting on coupled modelling involving SOC, the Hadley Centre and Reading University, together with the UGAMP and COAPEC communities, was hosted at SOC in February. Fifty-two people from 10 institutions attended. It was particularly gratifying to see a large number of students attend. Talks were given on a variety of coupled models from state-of-the-art present-day climate models to less-complex fast models capable of simulating millennial or longer timescales. An eddy resolving QG coupled model and limited area coupling were also discussed. The other main theme was interaction of physics and biology and talks ranged from global carbon cycle simulations down to the importance of subgridscale effects. A number of links and possible collaborations were noted, and the general feedback on the meeting was favorable.

A coupled modelling workshop was also held for the COAPEC community in March. Organised by Mat Collins and Lois Steenman-Clark at Reading, these workshops are primariliy designed to introduce users to the Met Office Unified model. The 2 workshops held so far have been tailored to the needs of the attendees. If you are interested in attending a similar workshop, or you have PostDocs or PostGrads starting who would be interested in attending a course, then please get in touch.

The second COAPEC annual meeting was held in Birmingham on 2-3 July, 2002 and was attended by some 60 members of the COAPEC community. A brief report of the meeting can be found on the COAPEC web site (under the Meetings link) but the titles of the talks are given here to whet your appetite!

Keynote - Coupled Research at the Hadley Centre	**Richard Wood (Hadley Centre)**
Seasonal Forecasting for Europe: The Role of the Atlantic Ocean	Steve George
Progress Towards Achieving a Balanced Air-Sea Flux Climatology	Jeremy Grist/ Simon Josey
Studying the Interannual Variability in the North Atlantic Overturning by Inverting Hydrographic Sections	Alberto Naviera
AO3 - Argo Floats in the South Atlantic	Helen Snaith
Discussion - Use of Observations in COAPEC and Data Requirements in COAPEC	
CMIP (Coupled Model Intercomparison Project)	David Webb
Does ENSO influence Europe?	Pierre-Phillippe Matthieu
Ocean-Atmosphere Coupling in Tropical Atlantic Warm Events and their Impact on European Climate	Adrian Matthews
The Interannual Variability of Atmospheric and Atlantic Ocean Heat Transports in HadCM3	Len Shaffrey
Oceanic Heat Anomalies in the HadCM3 100yr Control Run Data Set	Chris Old
Keynote - Sea Surface Temperature Forcing of Low-frequency Climate Variability over the North Atlantic - Europe Region	**Prof Laurent Terray (CERFACS)**
Idealized Experiments with an Idealized GCM	Maarten Ambaum
Climate Variability in the North Atlantic/ European Region	Evangelos Tyrlis
Synthetic Analog Seasonal Forecasting	Mat Collins
Synthetic Analog Seasonal Forecasting	Myles Allen /Mat Collins
Quantifying the Economic Value of Coupled Ocean-Atmosphere Model Ensemble Forecasts for Decision Making within the UK Energy Industry	Sergio Pezzuli
Climate Information for the Health Sector	Glenn McGregor
Discussion - User Driven Science within COAPEC	
Climate*Prediction*.com	Dave Stainforth
Model Studies in Support of Climate*Prediction*.com	Nick Faull
The Role of Ocean Heat Transport on Setting the Characteristics of Atmospheric Storm Tracks in FORTE	Chris Wilson
Building a Quasi-Geostrophic Coupled Model	Andy Hogg
A Scale Dependent Relaxation of Surface Fields in HOPE	Scott Osprey
Keynote - The Sensitivity of the Oceanic Overturning Circulation in a Coupled Climate Model to Global Warming	**Rainer Bleck (Los Alamos)**
Coupled Climate Modelling on PC Clusters	Alan Iwi
CHIME Strikes Again	Alex Megann
A Fast Coupled Model	Bablu Sinha
Progress Towards a Fast Coupled Model for Investigating the Role of Sea Ice in Climate Variability	Bob Marsh
Sea Ice Modelling	Doug Cresswell
Discussion - Model Development within COAPEC	
Seasonal Predictability of the Winter North Atlantic Oscillation	Mark Saunders

Notes from the Editor

If you have comments on the newsletter, or contributions for further editions, then please send them to me, the Science Coordinator :

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For any further information on the COAPEC programme, also contact me, or check the COAPEC web site:

http://coapec.nerc.ac.uk

And finally...

...responses may be a bit slow until March when I formally return from maternity leave.